NASA
National Aeronautics and
Space Administration

Information Summaries

Pushover-Pullup

Background

Some airplanes, especially rocket-powered research airplanes or highly maneuverable fighters, have very transient flight characteristics. Flight time is usually quite short due to limited quantities of fuel, and speed and altitude are constantly changing throughout a flight. For these vehicles the flight test methods requiring stabilized trim shots and slow, carefully controlled and steady conditions, are not very practical. Post flight analysis methods have been developed using advanced mathematics to apply corrections for the transient conditions, and several short, specialized maneuvers have been developed for this class of airplane. The Pushover-Pullup (or "roller coaster") is one such maneuver. It will provide lift and drag, longitudinal stability, and longitudinal trim over the angle of attack range covered by the maneuver. Pushover-pullups, along with control pulses, have been the primary maneuvers used to obtain aerodynamic flight test data for rocket-powered research aircraft.

1. Specific Objective of the Test

Determine the variation in lift and drag, the longitudinal stability and the elevator trim requirements over a range of angles of attack at a particular flight condition of speed and altitude. If the maneuver is performed at a constant thrust setting, the thrust must be determined independently in order to accurately define the lift and drag. If the aircraft is gliding, such as after rocket burnout for a rocket powered aircraft, the measurements represent the final values of lift and drag for the airplane.

2. Critical Flight Conditions

There are several conditions that will influence the values for lift, drag, longitudinal stability and trim. The important ones are:

- Airspeed
- Altitude
- Mach number
- Configuration (flaps and landing gear position)

Many of the flight conditions for a pushover-pullup are easily identifiable for a particular maneuver (such as weight, center of gravity, dynamic pressure), but there is little effort to try to control those values to a particular desired condition. Although the primary variables of interest are angle of attack and dynamic pressure, the flight conditions are identified to the pilot in the more common terms of airspeed and altitude. A good engineer will check to insure that the requested maneuver will not exceed a flight limit on the aircraft. The ideal Pushover-Pullup would gather data over a range of angles of attack both above and below the starting value, and would do so while holding each of the other variables (such as airspeed) at some fixed value. Since this is not practical in the realm of a free-flying aircraft, the maneuver is tailored to minimize these variations since they must be corrected in later analyses.

3. Required Instrumentation

The parameters usually measured and recorded during a pushover-pullup are shown in Table (1-1):

Table 1-1

Listing of Instrumentation Perameter

Parameter	**Used For**
Airspeed	compute mach and dyn. pres.
Pressure Altitude	
Outside Air Temperature	
Normal Acceleration	compute normal force, Fz.
Long. Acceleration	compute chord force, Fx.
Elevator Position	longitudinal stability and trim
Angle of Attack	longitudinal stability, lift and drag
Pitch rate	correct for non-steady conditions

The key parameters are angle of attack, and highly accurate measurements of normal and longitudinal accelerations. The acceleration measurements are usually obtained using sensitive accelerometers mounted near the aircraft's center of gravity, and carefully aligned with the axis of the aircraft. An alternate source of accelerations is the Inertial Platform commonly used for accurate navigation in modern military aircraft and commercial airliners.

A continuous time history of these parameters is needed for the entire maneuver. A sampling rate of at least 10 data samples every second is necessary to accurately record the maneuver, and each data sample must be accurately time-correlated with the data samples of the other parameters. That is, we must be able to relate a particular measurement of angle of attack with a corresponding measurement of normal and axial acceleration as well as elevator position at the same instant in time. Measurements of pitch rate and dynamic pressure are needed to apply small corrections to account for the non-steady conditions of the maneuver.

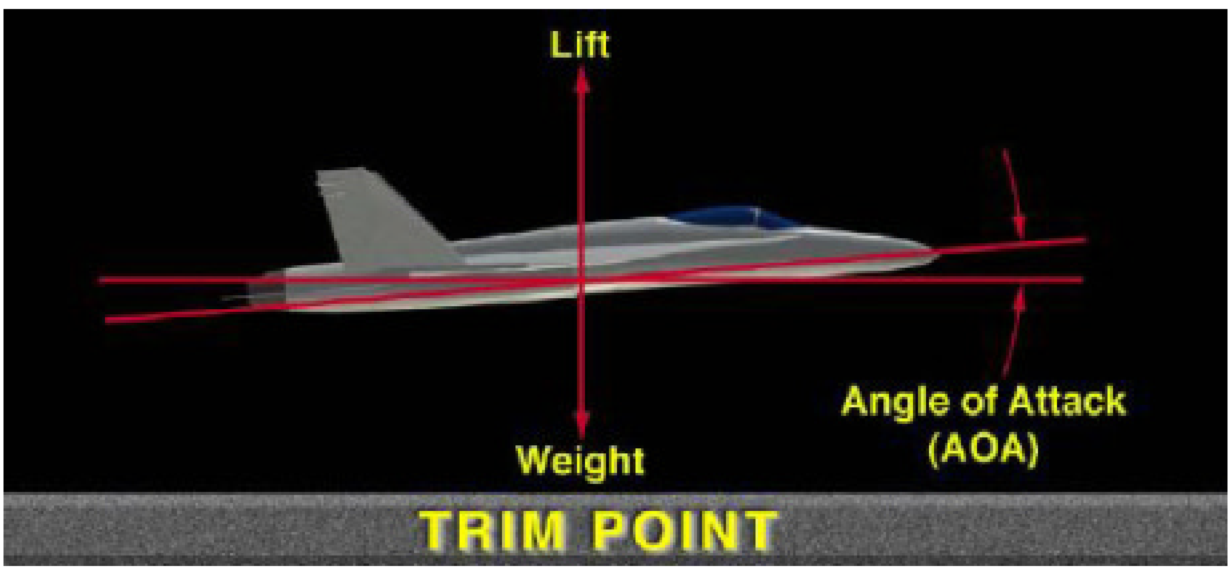
4. Starting Trim Point

The pushover-pullup, if flown properly, will obtain the desired data over a moderate angle of attack range for one flight condition of Mach number and altitude. The flight test engineer will establish a table of flight conditions where pushover-pullups are desired. This table usually calls for particular speeds, altitudes and aircraft configurations covering the entire flight envelope of the airplane. The range of angles of attack for each maneuver are usually established to provide overlap with data from other flight conditions. A typical sample table of flight conditions for pushover-pullups is shown in Table (1-2). Notice that a pushover-pullup does not have to start from a stabilized level flight condition. It can be performed during a climb or descent, or even during a turn. The only stipulation is that the airspeed be relatively constant at the beginning of the sweep in angle of attack.

Table 1-2

Table of Pushover-Pullover Test Conditions

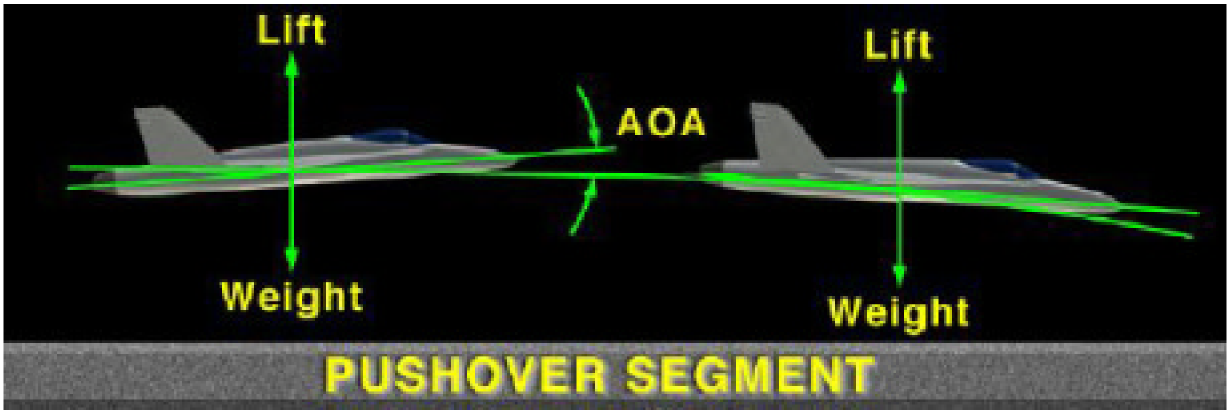
Config.	Alt.	Airspeed	Mach	AOA start	AOA Sweep
CLEAN	10,000	160	.3	9	5 to 15
		300	.54	.4	0 to 8
	20,000	250	.55	5	2 to 12
		350	.75	3	0 to 7
	30,000	200	.54	6	3 to 12
		350	.90	3	0 to 7
GEAR, FLAPS	5,000	120	.20	8	5 to 15
		180	.30	3	0 to 7



Center Trim Point

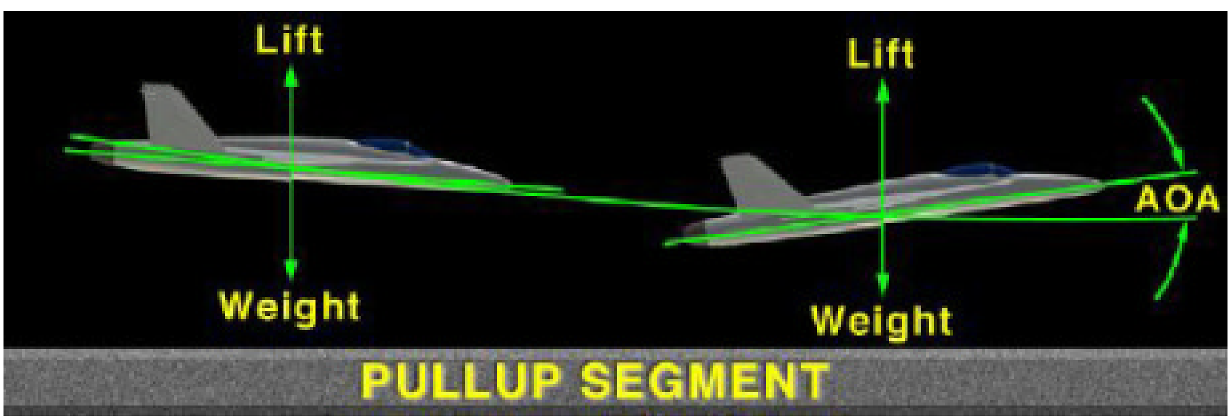
5. Description of a Pushover-Pullup

The pilot establishes the airplane at the desired speed, altitude and starting angle of attack. In a slow, smooth and continuous maneuver, and using only the pitch control, the pilot slowly reduces the angle of attack until the lower aim value of angle of attack is reached. During this portion of the maneuver the lift will be less than the weight and the aircraft will e ºer a slight dive.



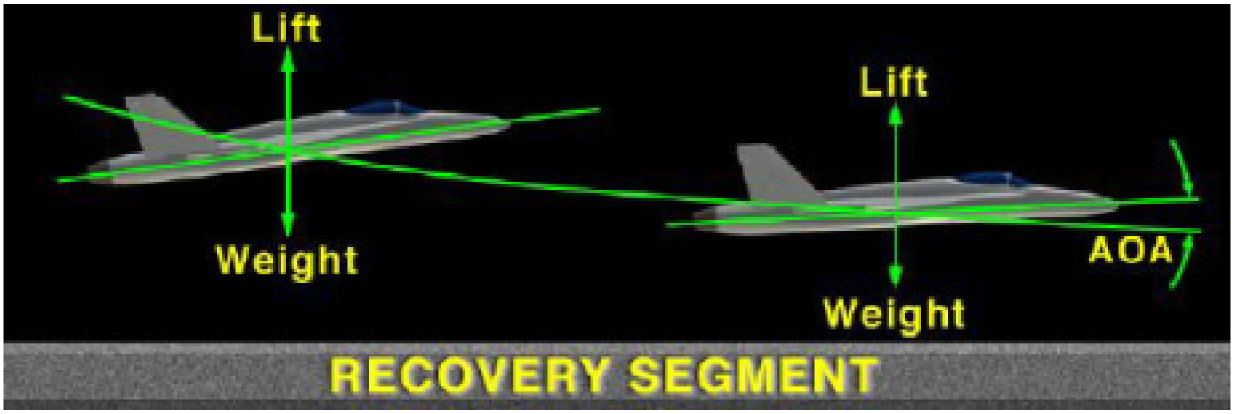
Pushover Segment

The slight dive, combined with the lower drag at low angle of attack, will cause the speed to begin to increase. Without stopping at the low angle of attack, the pilot reverses the pitch control, and the angle of attack is smoothly increased until the upper aim value is reached. The lift will now be greater than the weight and the aircraft will recover from the dive and may even begin a slight climb.



Pullup Segment

The increase in drag at the higher angles of attack, combined with a slight climb will cause the speed to stop increasing, then begin to decrease. The pilot then slowly reduces the angle of attack to the starting value, and the speed will restabilize close to the starting value.



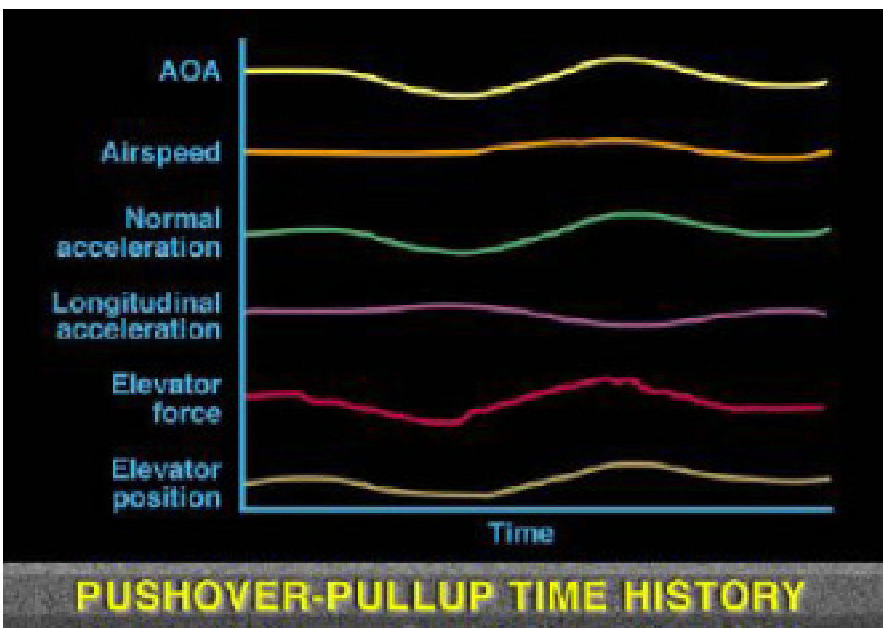
Recovery Segment

The intent is to keep the airplane in trimmed flight throughout the maneuver and to avoid any oscillations. The entire maneuver is normally completed in less than 15 seconds. The pilot will attempt to balance the pushover segment and the pullup segment such that the slight speed buildup that occurs during the pushover portion is balanced by the speed loss during the pullup, and the ending condition is approximately the same as the starting point.

6. Measures of Success

A successful pushover-pullup will meet the following test criteria:

- All instrumented parameters were recorded properly (see Table 1-1).



Pushover-Pullup Time History

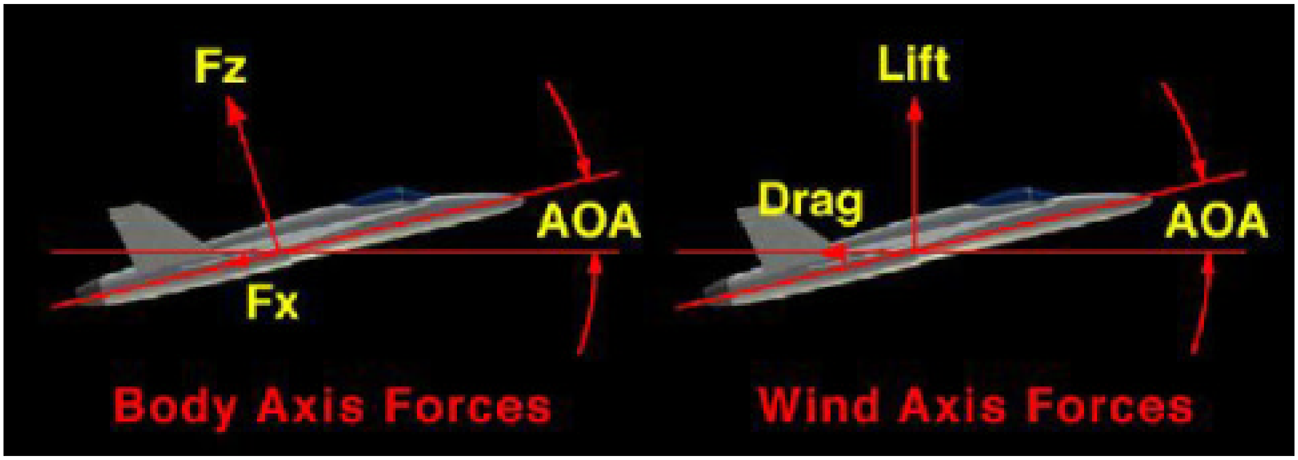
- Speed variations during the maneuver were about the same amount above and below the starting value.
- The maneuver was smooth and non-oscillatory

Assuming that the two accelerometers were carefully aligned with the fuselage centerline, the measured values represent the accelerations along the aircraft centerline, and perpendicular to the centerline. These forces can be computed using Newtons first law as follows;

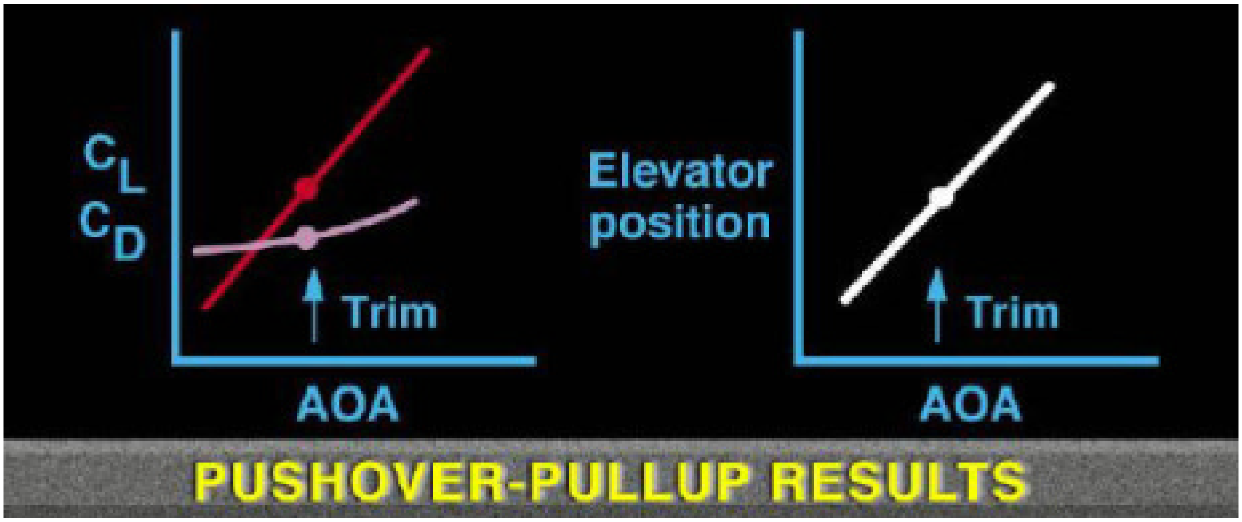
- Fx = ax*M = ax*(W/32.2)
- Fz = az*M = az*(W/32.2)

Lift and drag, however, are commonly referred to the wind axis system, that is, the x axis is aligned with the direction of flight rather than the fuselage centerline. In order to calculate the lift and drag we must convert the body-axis forces (Fx and Fz) to the wind axis system (D and L) by resolving each measurement through the angle of attack, (AOA). This is accomplished using the trigonometric relations and the following equations;

- D = Fx*cos(AOA) + Fz*sin(AOA)
- L = Fz*sin(AOA) - Fx*cos(AOA)

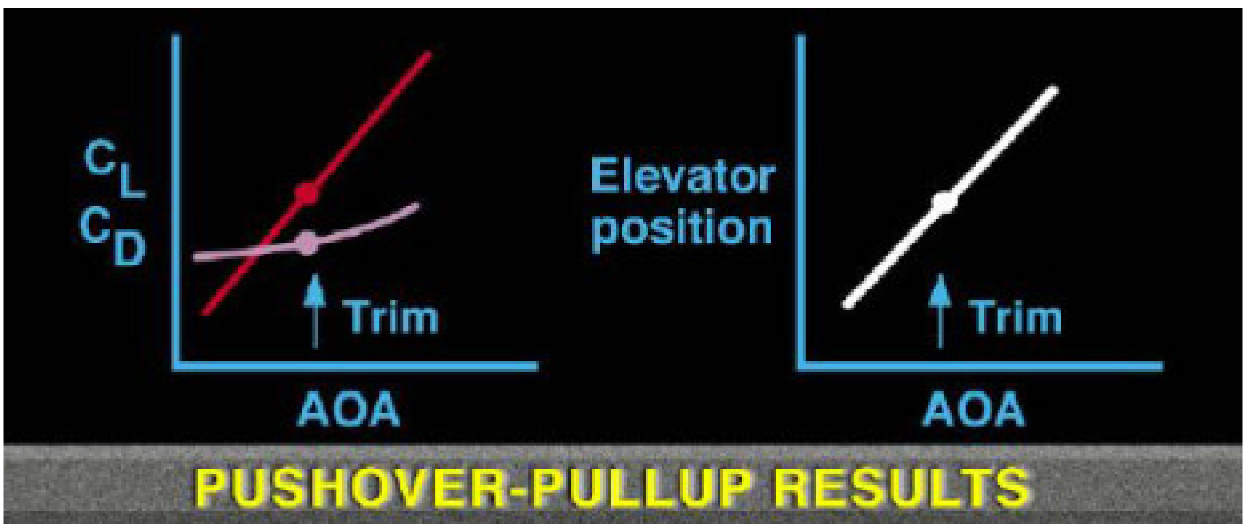


The resulting lift and drag data can now be plotted vs angle of attack and can be used in other, more complex, equations to predict range, maximum speed, turning capability, etc. for the aircraft.



Pushover-Pullup Results

The longitudinal trim characteristics and longitudinal stability can be identified by plotting the elevator position vs normal load factor (as was done for the Windup Turn) and also vs angle of attack. Positive stability is indicated by the slope of the elevator position vs angle of attack, that is trailing edge-up elevator is required to produce an increase in angle of attack.



Pushover-Pullup Results